NASA STTR 2015 Phase I Solicitation

T12   Materials, Structures, Mechanical Systems and Manufacturing

Lead Center: HQ

Materials, Structures, Mechanical Systems, and Manufacturing This topic is extremely broad, covering five technology areas: materials, structures, mechanical systems, manufacturing, and cross-cutting technologies. The topic consists of enabling core disciplines and encompasses fundamental new capabilities that directly impact the increasingly stringent demands of NASA science and exploration missions.

Subtopics

T12.01 Advanced Structural Health Monitoring

Lead Center: LaRC

Participating Center(s): JSC

This subtopic seeks new and innovative technologies in structural health monitoring (SHM), integrated vehicle health management (IVHM) systems, their corresponding analysis tools, and smart materials. Advanced structural composites and sensors with the potential to enable or enhance distributed damage detection for aerospace vehicles and spacecraft are sought. Example systems should allow for detection of damage states including corrosion, electrostatic discharge, delamination, cracking, microcracking, porosity, fiber breakage, impact damage, micrometeoroid orbital debris impacts on orbit, and general material property degradation due to aging. The innovative introduction of smart aspects to composite structures, for example, autonomous healing, shape memory, or piezoelectricity, is of interest. Such structures could allow for the realization of the mass reduction that composite materials have promised for spacecraft through enhanced damage tolerance. The addition of multi-functionality would be an asset towards improving overall system efficiency.

NASA is evaluating advanced composite structures due to their relatively high strength, light weight, and potential low production cost. Currently, damage tolerance concerns require that much thicker and heavier composite structures be manufactured to compensate for potential damage, and therefore the weight savings that composites promise has not yet been achieved. Smart sensor systems and smart structural composites could address this issue of damage tolerance, thereby allowing composites to be far lighter. Development of advanced technologies is required to improve the capability to better detect damage during manufacture and lifetime. Determining the extent of damage and/or autonomous healing of damage will also reduce the complexity of composite maintenance and increase performance lifetime and reliability.

This STTR seeks to enable the creation of smart composite systems and smart sensor systems for extended structural life monitoring and/or self-repair. Primary material systems for this STTR can include metals, but it is highly desirable to target carbon composite structures. Inclusion of smart or enhanced materials such as

piezoelectric, shape memory, and self-healing will be highly advantageous. Other potential sensors are: Surface Acoustic Wave (SAW)-based sensors, passive wireless sensor-tags, flexible sensors for highly curved surfaces direct-write film sensors, and others. Sensor systems can include sensors that can be applied post-manufacture of the structure. All systems will provide information about location and extent of the structural deficiency. It is not required but considered highly advantageous to directly relate to a measurable material property such as remaining material strength, density, etc.

Suitable target structures include but are not limited to primary and secondary structures, including vehicle, habitat module, and pressure vessel structures. Target structures may be relevant to either existing or future aerospace vehicles and spacecraft. SHM and IVHM systems applicable to the International Space Station are especially of interest, though the scope of the solicitation is not limited to this application. This subtopic is not intended for materials coupon-level work only; proposed systems should have a targeted demonstrator structure identified as a deliverable.

In Phase I, composite samples or prototype sensor systems will be fabricated and tested to demonstrate basic functionality of the material or sensor system. The targeted demonstrator structure will be identified, and critical test environments and associated performance predictions will be defined relative to the final operating environment. Deliverables include composite samples, sensors, associated test data, predictions, and lessons learned.

In Phase II, while full-scale demonstrators are not required, scaled-up systems will be built in application-appropriate geometries. Demonstrators will be tested in a simulated operational environment for demonstrate of performance in critical areas. Further scale-up requirements will be defined, and performance predictions will made for subsequent development phases. Deliverables will include samples and the associated test data, sensor hardware and predictions.

T12.02 High Temperature Materials and Sensors for Propulsion Systems

Lead Center: GRC

Advanced materials, structures and sensors are crosscutting technologies which are essential in the design, development and health maintenance/detection needs of components and subsystems that will be needed in future generations of aeronautics and space propulsion and power systems. Materials will require multiple or tailored functions that are designed to meet specific mission needs. Lightweight, high temperature, environmentally stable and multifunctional materials and reliable structures will be needed to meet the challenges of future aerospace systems. Improved temperature capability enables increased thermodynamic efficiency and improved performance.

- Develop innovative approaches to enhance the durability, processability, performance and reliability of advanced high temperature materials (metals, ceramics, polymers, high-strength fibers, composites, nanostructured materials and coatings to improve environmental durability.
- Develop and demonstrate hierarchical assembly of nano and microstructures to give ultra-lightweight materials with unique thermal, electrical, and/or mechanical properties.
- Multifunctional materials and structures as a means to reduce component weight.
- Physics based modeling tools that capture the modes of materials degradation in the extreme environments found in propulsion systems.

Innovative smart sensing methods and measurement techniques that can reliably assess component health in the harsh environments experienced in aerospace engines and vehicles that go beyond the limits of current sensing technology. Interest is in:

- Sensors and systems with a fast response, able to be used at high temperatures, low volume and weight, be minimally intrusive and possess high accuracy and reliability.
- Development of nano-sensor technology allowing sensors that are smaller, more energy efficient and the ability to provide more sensitive health assessments.
- Approaches to measure strain, temperature, heat flux, deflection, acoustics and/or acceleration of structural

components.
- Integration of sensors into systems (wireless, wired or fiber optic).

T12.03 Advanced Bladder Materials for Inflatable Habitats

Lead Center: JSC

This subtopic solicits advanced bladder materials for use in inflatable structures. Inflatable structures are a solution for increasing the volume and decreasing the weight and launch package for habitats, airlocks, and potentially other crewed vessels. Ideal bladder materials are low permeability gas barriers, durable over time, and do not degrade due to effects such as cold flow. Low permeability bladder materials that can withstand extreme cold temperatures (-90 °F), recover, and then deploy at low temperatures (-30 °F and -50 °F) while still maintaining low permeability rates (goal of 1.5 cc/100in^2/day/atm), are of particular interest. Multi-functional materials (self-healing, flame resistant, puncture resistant...) are also of interest, however, cold flexure is of prime concern. The bladder materials should also be low mass (goal of <6 oz./yd^2) and be able to be manufactured into complex shapes (such as dual curvature). Developments can include material development and testing, and/or demonstration of manufacturing techniques.

Phase I and/or Phase II deliverables should include material identification and/or development, and bladder materials flexure tested at various temperatures (such as room temperature, -30 °F, and -50 °F) and then permeability tested at room temperature. In addition, bladder materials can be lightly packed and folded and then taken to even colder temperatures (for example; -90 °F, -75 °F, and/or -60 °F) for an extended period of time (24 hours to a few months), allowed to recover, unfolded at cold temperatures (-30 °F and -50 °F) and then permeability tested at room temperature. Bladder materials should demonstrate the ability to be manufactured into complex shapes. The colder temperature the bladder materials can withstand (cold storage and deployment) and still meet the permeability goal, after recovery, the better the results.

T12.04 Experimental and Analytical Technologies for Additive Manufacturing

Lead Center: MSFC

Participating Center(s): ARC, GRC, JSC, LaRC

Additive manufacturing is becoming a leading method for reducing costs, increasing quality, and shortening schedules for production of innovative parts and component that were previously not possible using more traditional methods of manufacturing. In the past decade, methods such as selective laser melting (SLM) have emerged as the leading paradigm for additive manufacturing (AM) of metallic components, promising very rapid, cost-effective, and on-demand production of monolithic, lightweight, and arbitrarily intricate parts directly from a CAD file. In the push to commercialize the SLM technology, however, the modeling of the AM process and physical properties of the resulting artifact were paid little attention. As a result, commercially available systems are based largely on hand-tuned parameters determined by trial and error for a limited set of metal powders. The system operation is far from optimal or efficient, and the uncertainty in the performance of the produced component is too large. This, in turn, necessitates a long and costly certification process, especially in a highly risk-aware community such as aerospace.

State of the Art

This topic seeks technologies that close critical gaps between SOA and needed technology in both experimental and analytical areas in materials design, process modeling and material behavior prediction to reduce time and cost for materials development and process qualification for SLM.

What is the compelling need for this Subtopic?

Additive manufacturing is largely an emerging technology that shows great promise for the defense, energy, aerospace, medical and commercial sectors. Technological advancements are needed in the areas of:

- Real-time additive manufacturing process monitoring for real-time material quality assurance prediction.
- Reduced-order physics models for individual phases of additive manufacturing technique.
- Analytical tools to understand effects of process variables on materials evolution.
- Digital models to standardize the use of structured light scanning or equivalent within manufacturing processes.
- Software for high-fidelity simulation of various SLM phases for guiding the development, and enabling the subsequent verification.

The technology enabling to further utilization and certification for aerospace components. Almost all NASA Centers have capability in additive manufacturing and will benefit from this technology. This technology will accelerate growth in commercial development.

STMD/NASA/NARP/National - The subtopic is highly consistent with the technology objectives within the Strategic Space Technology Investment Plan and the NASA's technology roadmaps. The subtopic is also closely aligned with the National Manufacturing Initiative and the Materials Genome Initiative.